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Studie of the gamma deexcitation process of highly excited nuclear states.

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Document Version

Publisher's PDF, also known as Version of record

Publication date:

1978

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Koeling, T. (1978). Studie of the gamma deexcitation process of highly excited nuclear states. s.n.

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CHAPTER I

INTRODUCTION

The purpose of this thesis is to provide a description of the gamma-ray deexcitation process of highly excited nuclear states, formed in nuclear reactions. Because different reactions differ only in the way in which the highly excited states are initially populated, the calculations presented here can generally be applied to any reaction, provided that the initial population is properly chosen. The new feature of this calculation is the explicit separation of the total density of states in two pieces: a discrete part which is treated explicitly and a continuum part which is treated statistically. In this statistical part another new and important feature is that, in addition to classifying the states according to excitation energy (E), spin (J) and parity (π), the number of unpaired neutrons (n) and protons (z) is explicitly introduced. When calculating electromagnetic transitions between states we thus have three kinds of transitions: (i) continuum-continuum; (ii) continuum-discrete and (iii) discrete-discrete. The presence of a selection rule in the electromagnetic transitions between states in the continuum, introduced by the quantum numbers n and z , plays a very important and new rôle in determining the properties of the deexcitation process. This selection rule reflects the one-body nature of the electromagnetic transition operator and states that the quantum numbers n and z cannot change by more than two units in any given transition. Still another important difference between this calculation and others is the treatment of the discrete levels, which is done here using a model which, in addition to providing a good description of the known discrete states, also allows to take into account, to a good approximation, all other (experimentally unknown) collective states. Because these have large matrix elements to the low-lying states, they play an important rôle in the deexcitation process.

In this thesis two different reactions have been studied, viz. low energy neutron capture reactions and $(H.I., x n \gamma)$ -reactions. As mentioned above, the main difference between these two processes is in the initial population of the states. In fact, in the former case the initial population, representing the neutron capture state, has a sharply determined excitation energy, spin and parity, whereas in the case of $(H.I., x n \gamma)$ -reactions we are dealing with a population distribution, both in spin and excitation energy, representing the so-called entry-states, remaining after the neutron emission has taken place.

We begin in Chapter II by showing that the deexcitation process of a set of excited nuclear levels by means of gamma-ray emission is equivalent to a master equation system. After a more general introduction to master equation systems a master equation technique for the calculation of gamma-ray spectra and the analysis of feeding times in nuclear reactions will be presented. This technique, combined with a cascade technique, will then be applied to (n, γ) - and $(H.I., x n \gamma)$ -reactions in the remainder of this thesis.

In Chapter III neutron capture reactions will be described in detail. A survey of previous work in this field is given in section 3.1. Details of the present method will be discussed extensively thereafter. In particular, the level density formula, used for the description of the high-lying level continuum, the initial population, representing the capture state, and electromagnetic transition probabilities will be given comprehensive attention. The influence of the giant dipole resonance on $E1$ -transition probabilities is discussed in subsection 3.3.3. Results of calculations for the case of thermal neutron capture on ^{149}Sm are compared to experimental data. It will be shown that an experimental determination of multiplicity distributions of gamma-rays in coincidence with certain discrete transitions can be used as a means of extracting valuable information on the multipolarities of gamma-rays in the statistical gamma cascade deexciting the capture state.

In Chapter IV $(H.I., x n \gamma)$ -reactions will be discussed. The

procedure will then be applied to the reactions $^{150}\text{Nd}(\alpha,4n)^{150}\text{Sm}$, $^{158}\text{Gd}(\alpha,4n)^{158}\text{Dy}$ and $^{160}\text{Gd}(\alpha,4n)^{160}\text{Dy}$ and the results of the calculations will be compared to experimental data, obtained at the KVI by Ockels et al. (Oc78).

Since for the description of the low-lying (collective) states and the electromagnetic transition probabilities between them, we make use of the Interacting Boson Approximation (IBA-model) of Arima and Iachello (Ar75,Ar76,Ar78a,b), in Appendix A we give a brief outline of this model and of the calculated level spectra for the nuclei ^{150}Sm , ^{158}Dy and ^{160}Dy .

Finally Appendix B briefly describes the organisation and flow-charting of the various computer programs, involved in the calculations.